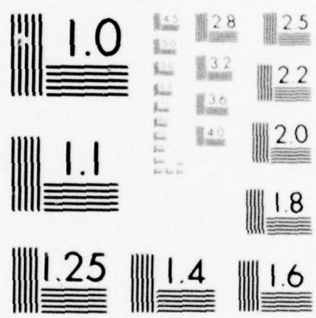
AD-A048 810 AAI CORP COCKEYSVILLE MD F/G 5/9
PART-TASK TRAINER FOR THE F-106A MA-1 RADAR/INFRARED FIRE CONTR--ETC(U)
SEP 77 K SLENKER, B W CREAM F33615-76-C-5028
UNCLASSIFIED AFHRL-TR-77-52 NL

| OF |
AD
A048810

END
DATE
FILMED
2-78
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

AFHRL-TR-77-52

AIR FORCE

HUMAN RESOURCES

AD A 048810

PART-TASK TRAINER FOR THE F-106A MA-1 RADAR/INFRARED FIRE CONTROL SYSTEM: DESIGN, SPECIFICATION, AND OPERATION

By

Kirk Slenker
AAI Corporation
Cockeysville, MD 21030

BERTRAM W. CREAM

ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

September 1977
Final Report for Period January 1976 – April 1977

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

This final report was submitted by AAI Corporation, Industry Lane, Cockeysville, Maryland 21030, under contract F33615-76-C-5028, project 1710, with Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson Air Force Base, Ohio 45433. Mr. Bertram W. Cream, Personnel and Training Branch, was the technical monitor.

This technical report has been reviewed and is approved for publication.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

DAN D. FULGHAM, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 18 AFHRL-TR-77-52 19

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) 6
PART-TASK TRAINER FOR THE F-106A MA-1 RADAR/INFRARED FIRE CONTROL SYSTEM: DESIGN, SPECIFICATION, AND OPERATION.

5. TYPE OF REPORT & PERIOD COVERED 9
Final rept.
Jan[illegible]76 – Apr[illegible]77,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s) 10
Kirk/Slenker
Bertram W./Cream

8. CONTRACT OR GRANT NUMBER(s) 15
F33615-76-C-5028 new

9. PERFORMING ORGANIZATION NAME AND ADDRESS
AAI Corporation
Industry Lane
Cockeysville, Maryland 21030

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
62205F
17100336

11. CONTROLLING OFFICE NAME AND ADDRESS
HQ Air Force Human Resources Laboratory (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE 11
Sep[illegible]77

13. NUMBER OF PAGES
~~26~~ 12 22p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
Advanced Systems Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base, Ohio 45433

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

16 1710

17 03

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
This research was funded by Aerospace Defense Command.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
behavioral data design techniques
instructional systems development (ISD)
instructor station design
part-task trainer
training simulation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This exploratory development effort was directed towards two objectives. First, refinement of a behavioral data design technique for the identification and specification of training device requirements; and second, use of these techniques to specify and procure a prototype, low-cost, functional part-task trainer for the F-106A Radar/Infrared Fire Control System. The design technique uses ISD data as a baseline and adds further analysis and information from the prospective operational users to determine: (a) Which of the training tasks actually need to be taught in the proposed device; and (b) The cost/benefit relationship of various degrees of simulation for each task. A one-year evaluation of the actual training impact of the device currently is being conducted. The design techniques used resulted in an inexpensive, reliable trainer with considerable flexibility inherent in the design.

2

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

1

Unclassified 402 203 SB

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SUMMARY

Problem

Two problems prompted this effort:

1. The operational problem was to design, fabricate and test a prototype, low-cost, functional part-task training device that would provide instruction and practice in normal and degraded mode procedures and skills required for operating the F-106A, MA-1 Radar/Infrared Fire Control System.

2. The technical problem was to refine a behavioral data design approach for determining: (a) which tasks need to be represented in such a trainer, and (b) the cost/benefit relationship of various degrees of simulation for each task.

Approach

Data from an instructional systems development (ISD) task analysis were used to identify the skills and knowledges necessary for operation of the fire control system. For each task, a determination was then made of the minimal degree of functional fidelity required to support effective transfer of training. Means were provided for instructor monitoring, guidance, problem control, and student feedback.

Results

A part-task trainer for the fire control system of the F-106A was designed, constructed and delivered. It currently is being used for student pilot training by the 2nd Fighter Interceptor Squadron, Tyndall AFB, Florida.

This trainer was designed by the use of a behavioral data design technique that represents a departure from more conventional ISD approaches.

The results of this analytical approach are a list of training tasks and display (trainer) requirements. By specifying the required trainer performance in this manner, a more cost-effective trainer configuration was developed, than if more conventional specification techniques were used. Simultaneously, the manufacturing contractor has more engineering flexibility due to the "performance" characteristics of the contractual specifications.

Although a one-year evaluation of the actual training impact of the device currently is being conducted, early reports from students and instructors using the device are highly favorable.

Conclusions

The design methods used represent a refinement of a basic approach first suggested in the early 1950's by Miller. Within the last few years, application and modification of this method has occurred at a number of organizations. This effort has resulted in a design technique that has application for both operational and advanced weapon systems. Although this method has many "new" features, it is basically a combination of well established and well known principles. In this effort, these techniques resulted in an inexpensive, reliable trainer with considerable flexibility inherent in the design.

PREFACE

The effort represented by this report was supported by funding from the Aerospace Defense Command and was conducted under the direction of the Advanced Systems Division, Air Force Human Resources Laboratory (AFHRL/ASR). This research was conducted under project 1710, Training for Advanced Air Force Systems; task 03, Training Implications of New Military Technology. Dr. Ross L. Morgan was project scientist. Mr. Bertram W. Cream was task scientist. The services of AAI Corporation, Cockeysville, Maryland, were obtained through contract F33615-76-C-5028, for which Mr. John Hammond was program manager. Mr. Bertram W. Cream was the Air Force technical monitor.

The authors wish to acknowledge technical, logistical and administrative support provided by the following personnel, without whom this program could not have been accomplished: Mr. Robert Coward and Major Norman Komnick, ADCOM/DOXI; Captains Allan Scott, (ADWC/OTI), and Charles Ickes (ADWC/2 FITS). Portions of this report dealing with design philosophy (Section III) can be found in an expanded form in a professional article by Messrs Bertram W. Cream, F. Thomas Eggemeier, and Gary A. Klein, "*Behavioral Criteria in the* Design of Aircrew Training Devices." Proceedings of the 19th Annual Meeting of the Human Factors Society, Page 260, October 1975. Credit is also given to Mr. Kenneth R. Boff, AFHRL/ASR, for contributions to the Evaluation Section of this report.

A 7-minute, 16mm color film (SPR 35-76) visually documents this effort and is available on loan from AFHRL/AS, Wright-Patterson AFB, Ohio 45433.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

PART-TASK TRAINER FOR THE F-106A MA-1
RADAR/INFRARED FIRE CONTROL SYSTEM:
DESIGN, SPECIFICATION, AND OPERATION

I. INTRODUCTION

This research project was initiated in response to a request for engineering services from the Aerospace Defense Command (ADC) (ESP-9762-1-75-4). The goal of the project was to provide a low-cost, part-task trainer to teach normal, degraded mode, and malfunction operation of the F-106A MA-1 Radar/Infrared Fire Control System. ADC specifically requested that the behavioral data design techniques, successfully demonstrated on the functional integrated systems trainer (AFHRL-TR-75-6(I, II)), be used for this project.

This report documents the approach used to design and develop the trainer. It outlines the principal objectives of the effort, and describes the system produced to provide the necessary training.

Much basic operational training currently is accomplished by use of either actual flight time or the use of simulators (if available). Such procedures have obvious training value. However, in the first case, considerable expense is involved. In the second, the full potential of the device often is diluted when it is used for such basic skill training as equipment familiarization, normal and emergency procedures and basic systems operation. By use of less costly training devices, full mission simulators may be used for real-time, complex training for which they are best suited.

With the above in mind, the major design input for this project was an analysis of the tasks required to operate the F-106A MA-1 Radar/Infrared Fire Control System. This task analysis, from a previously conducted instructional systems development (ISD) analysis, was provided by the Air Defense Weapons Center (ADWC), Tyndall Air Force Base, Florida. These task data were analyzed further by personnel of ADWC and the Air Force Human Resources Laboratory (AFHRL). Fifteen major tasks were identified as training objectives (see Table 1). Because of high task loadings, rapid response times required, complex system operation and the extreme importance of accuracy, the precise identification of each task essential to job performance was critical. The ADWC instructors provided the technical experience necessary for the identification of such tasks.

Using this data base, the next step was to design a training device (Figure 1) that would meet the training objectives, and to do this at a low cost. This also involved ensuring that tasks had a sufficient difficulty level so as to accurately reflect the high task loading incurred during actual hostile conditions. Towards this end, all design decisions were made with one object in mind: provide only that training content and difficulty required to train for that task in question, and no more.

Table 1. **Major Training Tasks**

Number	Description
1	Armament Safety Checks with Primary Armament
2	Armament Safety Checks with Secondary Armament
3	Radar Airborne Checks
4	Radar Lock on
5	Radar Lock on Despite Malfunctions and Degraded Mode
6	IR Airborne Checks
7	IR Lock on
8	IR Lock on with Malfunctions
9	Crossmode
10	Crossmode Malfunctions
11	Special Weapon Armament Selection
12	Missile Armament Selection
13	Delivery of Weapons–Radar Lead Collision
14	Delivery of Weapons–Pursuit Lock on
15	Failure to Deliver Weapons

The techniques used for design and to provide contractual specifications are discussed further in Section III. These methods have been shown to provide high quality training devices at low dollar cost.

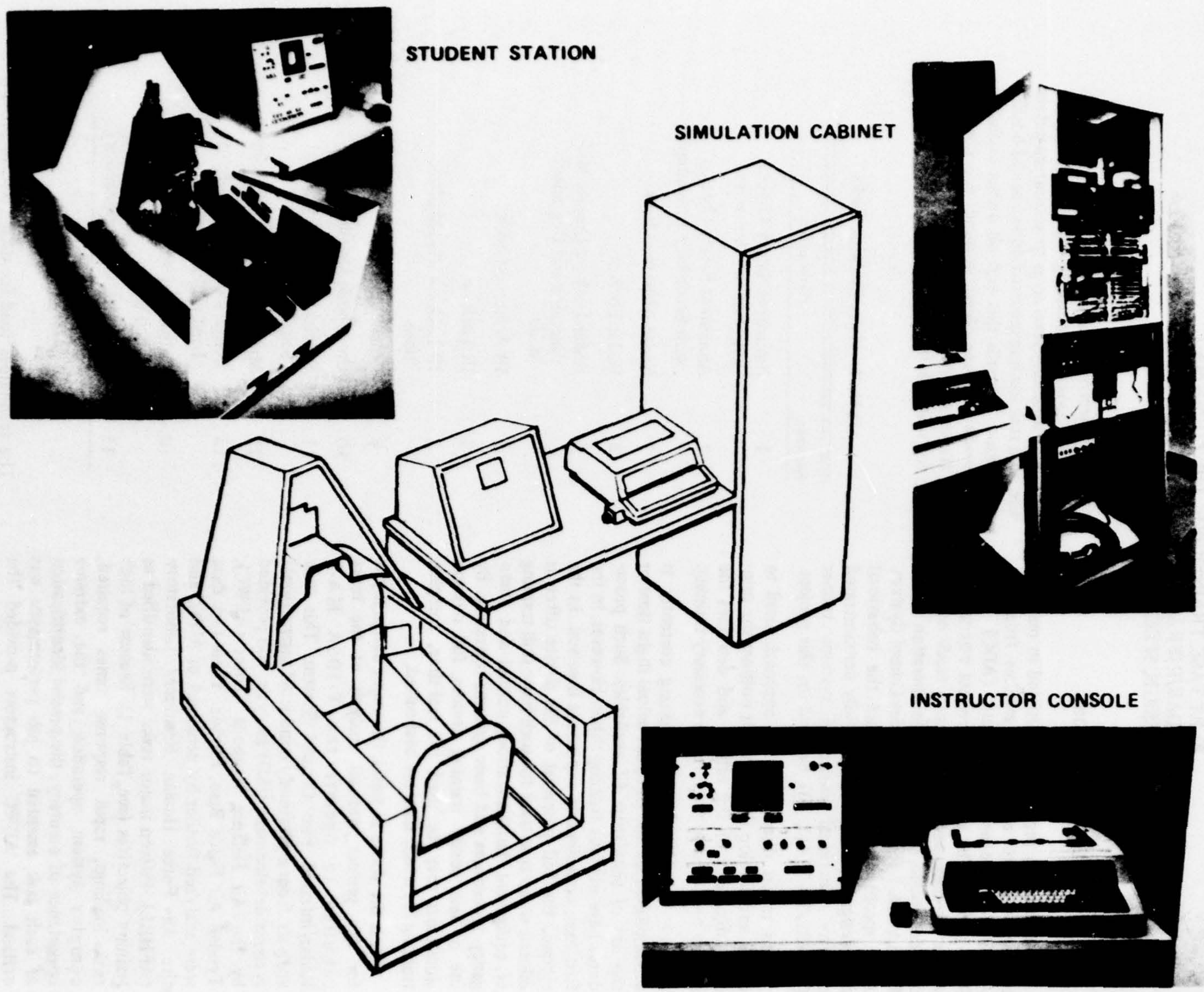


Figure 1. **F-106A MA-1 radar/IR part-task training device and instructor station.**

II. TRAINING PROGRAM

Effective operation of the MA-1 system is crucial to the successful completion of an intercept. The MA-1 permits the F-106 pilot to detect the presence of a target, determine its relative location and successfully engage the target with available weapons.

Effective use of the MA-1 is difficult for student pilots to learn for several reasons. Among these are: (a) the MA-1 has numerous modes of operation, (b) some procedures must be performed rapidly as well as accurately, (c) electronic countermeasures (ECM) activity can cause confusing and ambiguous displays that the student must learn to recognize and interpret, and (d) degraded system capability (due to malfunctions or ground clutter) requires the pilot to make adjustments and trade-offs that require good judgement developed through practice. The student-pilot must learn to recognize which mode is most appropriate for specific situations and which procedures should be followed for each mode. During an intercept, the MA-1 procedures are usually time critical; i.e., the proper procedures must be performed within critical time periods. With closing speeds of over 1,000 knots possible over a variable range, the pilot does not have much time to determine the proper sequence of operations required to effectively utilize the MA-1. ECM activity by the target can make it difficult for the pilot to distinguish the target and possible for him to lock on to a false target. The student must be able to recognize this ECM activity and configure the MA-1 to optimize the system for this environment. Finally, ground clutter and system malfunctions may degrade the capability of the MA-1 system. Either situation can make it very difficult to detect and acquire a target. The student must adjust and properly tune his display to minimize this reduction in capability. He must also use certain search and acquisition techniques that improve the probability of a successful intercept. All of these difficulties can be present in many combinations. Usually, he must make these determinations in the presence of a number of competing activities; e.g., flying the aircraft, managing fuel, and acquiring the target, all under severe time constraints.

Many of the procedures required to operate the MA-1 effectively can only be trained in a practice situation where a target, ECM activity, ground clutter and a variety of MA-1 malfunctions can be provided. Exposing student pilots to a practice situation using an actual aircraft is time consuming, expensive, somewhat hazardous, and may not be entirely effective for training for a number of reasons. Among these are: (a) practice areas are usually located some distance from an airfield—resulting in long transport times and high fuel consumption; (b) there are usually security and Federal Communications Commission (FCC) restrictions on the types of ECM maneuvers that can be employed during such exercises, resulting in less than comprehensive exposure of the student pilot to ECM; (c) there is no control over the MA-1 malfunctions that could occur during such an exercise, resulting in lost practice time in cases where the student pilot is not prepared to cope with a degraded MA-1; (d) the student pilot is denied the benefits that could be obtained if an instructor were able to observe his performance on the spot, resulting in the loss of immediate corrective feedback for at least some procedures; and (e) repeating an exercise several times is prohibitively expensive and impossible to do accurately.

The currently available MB-42 (F-106) simulator makes use of an actual MA-1 system. Unfortunately, this simulator has fidelity and reliability problems. Also it is near the end of its design life time. ADC currently is expending flight hours and time in the MB-42 simulator for teaching students cockpit procedures required to operate the MA-1. ADC felt that this was not a cost-effective utilization of these expensive and relatively limited resources. Consequently, it was decided to develop an economical but effective MA-1 Procedural Trainer. The training objective for this device was to permit student pilots to develop essential and desirable MA-1 procedural skills at low cost, thereby allowing full advantage to be taken of more expensive aircraft training. Overall, this approach was seen as improving the quality of training and permitting maximum use of every part-task trainer, simulator and aircraft flight hour.

III. DESIGN METHOD

Systematic methods have been developed for using task analysis data to specify training objectives (e.g., Air Force Manual 50-2; Air Force Pamphlet 50-58; Goldstein, 1974). These methods typically seek to identify the specific behavioral skills and knowledge required by graduates of a training program. These required skills and knowledge are matched against the actual ability of new students. The differences between current and desired skills define the training requirements of the contemplated training program. Such an approach can have several significant effects: (a) By expressing training requirements as behaviors

required for successful job performance, extraneous skills are not taught or paid for. (b) Because of the specificity necessary in describing objectives, training time may be reduced. (c) By developing precise statements of training requirements, evaluations of student progress and program effectiveness can be facilitated.

There are, however, important limitations to these techniques: (a) They are not sufficient for the actual design of the training device which frequently represents the major dollar investment of the program (Cream, Eggemeier & Klein, 1975; Klein, 1976a). (b) Difficulties sometimes are encountered in application of the techniques by unskilled personnel (Montemerlo & Tennyson, 1976). (c) By emphasizing training of adequate performance (mastering a task to a predetermined acceptable criterion) the techniques may be unsuited for development of devices to train high proficiency performance (Klein, 1976b; Miller, 1974). (d) The techniques do not adequately address design of a device for team or crew coordination training.

The design methods used for this project represent a "new" approach and refinement of a basic methodology first suggested by Miller (1953, 1974). Within the last few years, application and modification of the method has occurred at a variety of commercial and Government organizations. In its current state, this design method combines well-established and well-known principles with certain "new" refinements. Basic to the approach is the fact that all data used for this program were based on a collection and analysis process which involved a team of users, training psychologists, and simulation engineers. In each case, the objective is to provide early identification of training requirements in a form that allows its use for design of low cost functional part-task trainers.

Background documentation for the system; i.e., the ISD study, check lists, technical orders, regulations, manuals, and course syllabi, was used to develop detailed behavioral analyses, time lines, and functional flow diagrams of tasks to be trained. A complete description of the stimulus-response (s/r) conditions for each type of control and display involved for each separate task also was obtained. The analysis also included a listing of all the tasks and sub-tasks, and their sequencing. For each task and sub-task there was a description of initiating and terminating conditions, the actions required, as well as the relevant controls and displays. The task analysis described the conditions under which the s/r descriptions apply; i.e., constraints, relevant contingencies, malfunctions, and performance parameters. The user verified all aspects of the task analysis both during and after its completion.

After the initial data analysis had been verified, the team determined the specific capabilities required in the training device. The major issues were the selection of tasks to be trained and the degree of simulation fidelity necessary to accomplish the required training.

The selection of tasks and necessary fidelity required a more detailed analysis of specific tasks. In addition to the usual descriptive data collected, the user ranked each functional task and sub-task along three dimensions: criticality, frequency of performance, and difficulty of performance (C/F/D). These user rankings provided the data necessary for required fidelity decisions. They also served as a basis for performance measurement and instructor station design requirements. Tasks that the user rated uniformly high in C/F/D were identified for inclusion, while tasks rated low on C/F/D were not, unless they were necessary for the training of other tasks with higher ratings.

Tasks which were excluded from the training device were not simply ignored. Because the device was to be incorporated into a larger training program, tasks identified for training will either be trained in the device or handled elsewhere in the program. The specific determination of tasks to be included in the training device was made on the basis of the C/F/D prioritization, matched against available funds to establish a cutoff point.

Fidelity and Capability Decisions

Many training tasks require a fully functional system; i.e., one that faithfully duplicates all stimulus conditions. Others require partial fidelity and some do not require functional fidelity. The difficult issue is how to decide the correct level of fidelity necessary to support the tasks and their concomitant training requirements. Level of fidelity needed to accomplish specific tasks can be estimated roughly in terms of required cues and the required clarity of their presentation. The costs of obtaining various levels of fidelity can be discussed in terms of dollars, limitations in the state-of-the-art, and reliability difficulties.

By asking the user to explain why tasks are rated as high in difficulty, valuable data are provided about how the tasks should be incorporated into the trainer. For example, the lock-on task was rated high in difficulty. But, almost all of its subtasks were rated low in difficulty. By asking the

user why the task had received its high difficulty rating, it was learned that what made the lock-on task difficult was the relationship between the hand control and the display. This relationship had to be maintained in the trainer or there was a real danger of negative transfer. Had we simply collected difficulty ratings without further questioning, this crucial factor would not have emerged. Also it was learned that certain malfunctions affected the scope image in a way that prevented lock-on. During further discussions, the users concluded that there was no need to include all such malfunctions in the trainer since the malfunctions did not support the training of the hand control/display relationship. In addition, by omitting these malfunctions, the users had more money to spend on improving fidelity in other areas or buying additional training capability.

Instructional Features

The advancement of digital computer technology has greatly increased the range and sophistication of available instructional features (Smode, 1974). Automatic sequence control, capabilities for demonstration, record and playback, parameter freezes, and utilization of preprogrammed scenarios are among the features made available by technological advances. However, the evaluative matching of instructional features to specific tasks is an area that has been largely neglected.

For this device, the instructor station was designed to support the instructor in the performance of four functions: controlling and setting up tasks, measuring the trainee's performance of the tasks, displaying and recording these measurements in a useful form, and presenting these measurements and other instructional communication as feedback to the student.

Each feature of the instructor station was evaluated along a variety of dimensions: the demands the feature would place on the instructor's time and attention, the anticipated frequency of use of the feature during training, computational demands placed on the computer system by use of the feature, anticipated reliability and maintainability problems of the feature, location of the instructor, cost of the feature, and its actual support of training. For example, since all tasks were of short duration, replay capability was judged unnecessary, but a freeze capability to allow instructor explanations was included. A description of the instructor station layout and function is provided in Section V.

IV. TRAINING OBJECTIVES

The trainer was designed to achieve specified behavioral training objectives. The purpose was to provide a situation where specific MA-1 procedural skills could be acquired as a part of the overall F-106A pilot training program. This implies that the behavioral training objectives for the trainer could not be achieved more economically using other means of training, and that the design of the trainer had to be compatible with the overall F-106A training program.

In designing a training device there is usually a tendency to try to provide a wide range of training capabilities, as though the device were going to be the sole means used for training. A more cost-effective approach to designing a training device is to include only those capabilities which are required to achieve specific training objectives. The MA-1 procedures trainer is only one of a series of training opportunities for the F-106A student pilots. Training opportunities range from indoctrination training aids to on-the-job training in an active squadron. It was clearly important for the ADWC technical representatives to work closely with AFHRL and the contractor to help identify those training objectives that required training using the MA-1 procedures trainer and those better trained using existing training opportunities.

Air Force personnel representing ADC, ADWC and AFHRL developed a set of behavioral training objectives for the device. Fifteen (15) major tasks were identified as training objectives (see Table 1). These tasks were selected for one of two reasons. One reason was that the tasks were judged to be either critical or difficult in operating the MA-1. The other reason was that the tasks involved displays not available with the current flight simulators. Most of the radar and armament tasks fall in the first category. All of the infrared (IR) procedures are included since they also are critical, especially in the high ground clutter environment. A number of MA-1 malfunctions were included for the same reason (see Table 2). ECM training was not included since the current simulator provides a good jamming simulation and this is a more advanced task. The radar or IR tracking task was not included because this skill can be effectively taught in the current simulator and is primarily a flying skill. The pilot must fly the aircraft to center the steering dot after lock-on. This task would also require the flight controls to be functional, thus greatly increasing the cost and complexity of the trainer.

Table 2. **Simulated (Degraded Modes) Malfunctions and Anomalies**

Type	Description
Radar Degraded Performance	Break Lock to Chaff Single Bar Sweep Break Lock B Sweep Jump Missing Range Gate Marker Noisy B Sweep
Radar Lock on Prevented	*Antenna Drives Down* Range Gate Drift
IR Degraded Performance	Single Bar Sweep Break Lock Blank Display
IR Lock on Prevented	Prevent Lock
Radar/IR	Cross Mode Disable Stable Table Precess Re-erect Override
Radar Anomalies	*"Christmas Tree"* Very High Clutter
Weapon Malfunctions	AIR-2A Circuit Breaker Overload

For each task, a detailed list was compiled listing the desired student operations, MA-1 system reaction to those operations, and the desired scope presentations. For each malfunction, not only the desired appearance, but also the desired student corrective actions were compiled. In addition, common student procedural errors were listed along with the displays and MA-1 response to these incorrect operations (see Table 2). Some of these procedures required the definition of the degree of fidelity required in the MA-1 scope simulation. For example, the radar lock-on task required the simulation of chaff for two reasons. Chaff greatly complicates the radar lock-on task and the currently available simulation is ineffective. Similarly, the radar lock-on task requires at least a simple ground clutter simulation. the clutter can make it difficult to detect and lock-on the target and, currently, no simulation capability is available.

Hardware Constraints

There were a limited number of hardware constraints for the trainer. These constraints concerned the need for cost effectiveness and reliability in the design. It was decided that the cathode ray tube (CRT) display system would not be an aircraft unit so as to avoid its high cost and unreliability. Cockpit layout matched the real aircraft in appearance and location of displays and controls, and they were also designed to withstand the wear and tear of many years of use. The computer had to have adequate spare capacity, with *the necessary peripherals* and a backup input device.

It was necessary to design the instructor's station so as to permit easy monitoring, observation and correction of the student. The instructor station CRT display had to be identical to the student's. Finally, it had to be designed to allow the instructor to operate with little special training.

In summary, the list of training tasks and display requirements, plus the few hardware constraints formed the requirements for the MA-1 Radar/IR Part-Task Trainer. The requirements were determined by carefully establishing the behavioral training objectives of a part-task trainer designed to improve the F-106/MA-1 training program. By specifying the performance in this manner, a more cost-effective configuration of the trainer was developed than if more conventional specification techniques were utilized. The requirements ensured that the trainer would accomplish the training tasks needed to improve the F106A training program. Simultaneously, the designing and manufacturing contractor was provided considerable flexibility in producing a cost-effective, reliable trainer.

V. TRAINER DESCRIPTION

Design Approach

The MA-1 Radar/IR Part-Task Trainer was designed and manufactured by AAI Corporation to meet the previously discussed requirements. The heart of the design approach is the technique used to simulate the MA-1 CRT system. The actual radar display in the aircraft is a 4-gun, multi-mode storage tube that displays non-stored characters and stored radar returns or stored IR video simultaneously. The entire scope face is illuminated to an ambient intensity called the flood level. The non-stored characters are written

as bright lines or circles on the scope face and the stored data are written as dark images on the flood level. The trainer avoids using a storage scope entirely, using instead a conventional, high-quality, three-axis CRT. The storage effect is simulated by digitally generating a raster over the entire scope face. The raster is refreshed 54 times per second, causing the image to appear as if it is stored on the scope face. Only 16.4 milliseconds of the 54th of a second are needed to generate the raster; during the remaining two milliseconds the characters are drawn on the display in a fashion similar to the actual airborne unit. Since the focused CRT beam actually traces out each character several times during this interval, the characters appear much brighter than the simulated flood level and stored data displayed during the raster interval. The 54 Hz refresh rate is sufficient to eliminate any flicker, thus giving the impression that the information is being stored. Also, it is adequate to conceal the fact that the characters and stored data are generated sequentially instead of simultaneously as they are in the actual unit.

The display simulation system is shown in Figure 2. The CRTs for both the student and instructor station are Tektronix 604 display monitors; proven high-quality, high reliability, but low-cost instruments. The character generation consists of random access memory into which the system computer loads the data that define the type, position, size and intensity of up to 16 characters. These data control multiplying digital-to-analog (D/A) that produce the appropriate deflection and intensity signals during the character interval.

The raster-generating hardware is somewhat more complex and is divided into several subsystems. The X, Y sweep signals are generated by analog sweep generators that are synchronized to the digital circuits that produce the Z axis signal. The clutter simulation is fairly simple. No large contrasting features, such as mountains, lakes, shorelines, etc., are simulated. Instead, a fairly uniform terrain is simulated using random numbers. These numbers are modified by range attenuation and antenna elevation pattern effects to produce the important clutter characteristics such as the altitude line, side lobe returns, and the main lobe (main bang) return. Target generation is accomplished by storing position, size and intensity data for 16 targets in random access memory and using those data to modulate the Z axis during the raster interval. One target is used as an aircraft, 14 as chaff and one as the main bang. The range gate, erase sweep and B sweep are all generated in a similar fashion. All of these outputs are combined together in the summing logic along with IF gain, video gain, and fading and erasing effects for the simulated stored image. The result is multiplexed with the character and IR subsystem output to produce a Z axis signal.

In the aircraft, the IR subsystem produces the IR video display modulation for the Z axis. Up to four successive sweeps of the IR seeker can be displayed simultaneously due to the storage scope feature. To simulate the sweeps, four identical circuits store the position, size and storage time data, one circuit for each seeker sweep. The computer writes these data when the seeker sweeps. The storage time data are used to reduce the intensity of each video sweep as a function of the erase control setting and the elapsed time since the computer wrote the data (i.e., since the seeker passed this point). Therefore, the video image appears to fade across the scope after a few seconds unless it is rewritten sooner by the seeker. The erase control determines the length of time that a particular point is stored. The output is combined with the target, clutter and character Z data to produce the Z axis output.

All of these subsystems rely very heavily on the data loaded by the computer. In general, the hardware does little more than synchronize the IR, clutter, target, range gate, B sweep and erase sweep data with the raster sweep signals and combines these outputs along with the character data to produce the X,Y,Z scope drive signals. The computer data determines when, where, how big, and how bright all of these items will be displayed. All control inputs are read into the computer from the student cockpit and the instructor's console, and the real-time program determines from these inputs what should be displayed on the scope. The result is that a very large amount of simulation is done in the software. For example, all antenna and seeker movements are done in the software. The control grip position and antenna controls are read nine times per second. The real-time program determines the antenna mode such as search or manual and outputs its position 54 times per second. If the MA-1 is in the search mode, the output position changes each update as the antenna traces out the search pattern. The 54 Hz update rate is more than adequate to give the appearance of a smoothly moving antenna.

By placing the primary burden of simulating the MA-1 system in the software, a great deal of flexibility was realized. This flexibility is important for several reasons. First, the airborne MA-1

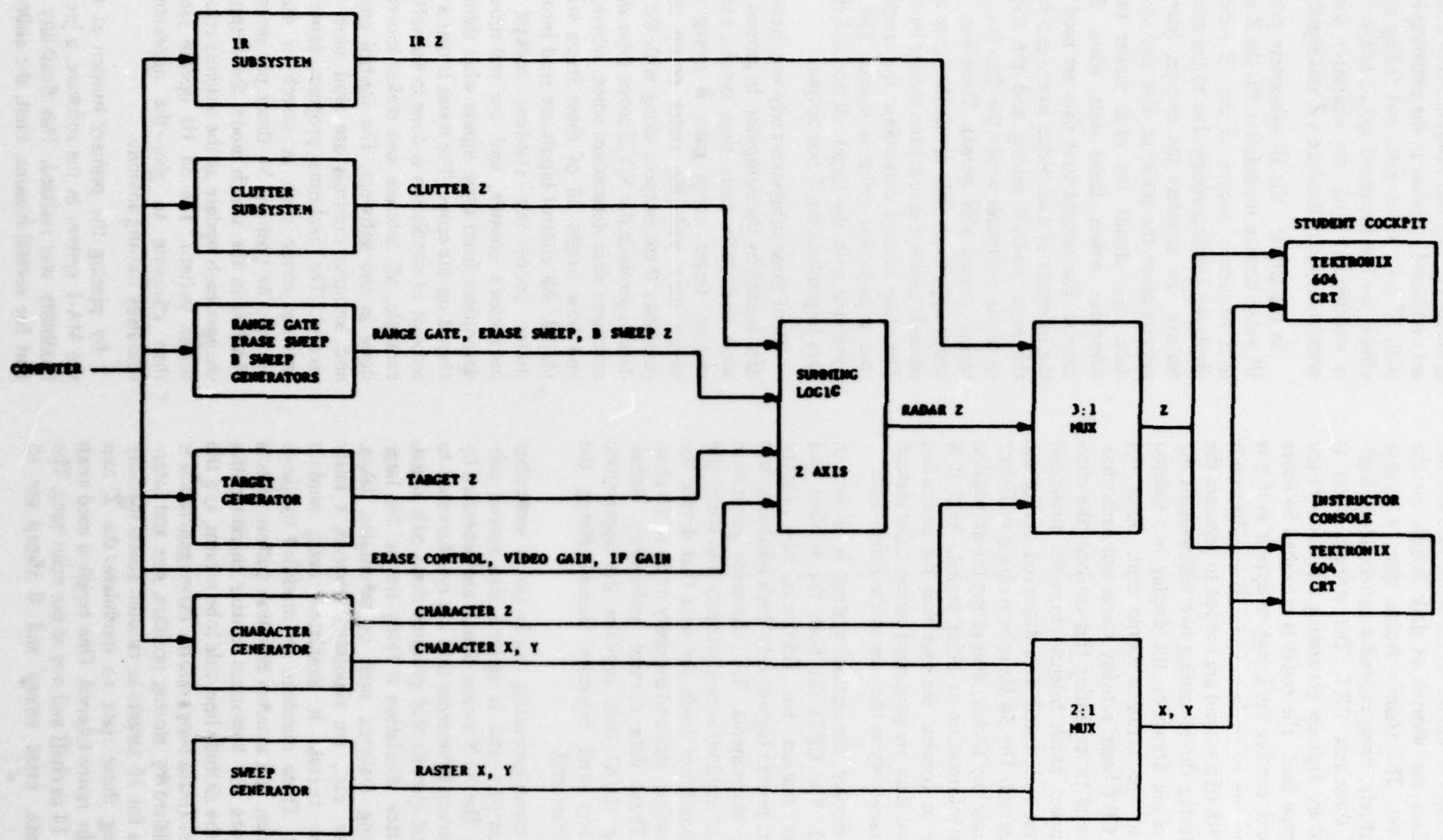


Figure 2. **MA-1 radar/IR part-task trainer display system.**

system is very complex, has many modes and complicated control logic. A tremendous amount of hardware would have been required to model this logic. Second, the airborne MA-1 itself contains a digital computer that controls weapon functions and the display formats. The computer program tape is updated periodically. By simulating all of these functions with software it is much easier and less expensive to keep the trainer configuration compatible with the aircraft configuration. Finally, software simulation makes it easier to correct and adjust the trainer performance to more closely match the desired response in subjective details. Although the training objectives were developed and the MA-1 system was defined with many inputs from F-106A instructor pilots, certain subjective aspects of the trainer response could only be refined after the pilots had an opportunity to operate the trainer. The inherent flexibility in this approach made it very easy to quickly adjust the response to achieve a satisfactory simulation.

The computer selected to control the trainer is an Interdata Model 7/16 with 16K halfwords of core memory, and a high-speed arithmetic logic unit. The Interdata 7/16 is a fairly powerful minicomputer that is relatively easy to program. The Interdata I/O structure provides a rather simple high-speed interface with the display system hardware. A Carousel Model 35 keyboard/printer with a paper tape reader is used as the instructor's interface with the computer. A Remex high-speed paper tape reader/punch is used as the bulk data input/output device. This system provides a good cost/performance ratio that is consistent with the trainer objectives.

For the instructor's station (Figure 3), high quality commercial-grade switches and indicators are used. Functional switches are used instead of a general purpose keyboard to minimize instructor training requirements. Each switch is clearly labeled with its function. A number of indicators are also included to indicate to the instructor certain critical switch selections the student has made. Of course, the instructor's console also includes a scope repeater that displays the same imagery that the student sees.

The cockpit (see Figures 4 and 5) contains six functional control panels that consist of controls and indicators only. High-quality, commercial-grade controls and indicators are used here also, except for a few special annunciators, indicators and the control stick. All other cockpit controls and indicators were photographically produced, etched aluminum panels that resist abrasion in day-to-day use.

VI. TRAINER CAPABILITIES

The operation of the trainer is rather simple (see Table 3 and Figure 3). The instructor enters the student's name, the sortie number and the date on the keyboard. Control is then automatically transferred to the instructor's console. The attack profile and target type is selected next. Three profiles are available. The front attack is a high altitude pass which starts with the interceptor at 32,000 ft. initially, and an airspeed of 500 knots. The target is at 37,000 ft. and is closing at a rate selectable by the instructor between 700 and 1,100 knots. The initial range is 40 nautical miles. There are also two stern attacks available. The stern look-up profile starts with the interceptor traveling at 2,000 ft. at 310 knots. The target is at 3,000 ft. closing at a rate selectable between 0 and 400 knots. The stern look-down attack profile also starts with the interceptor at 2,000 ft. with 310 knots airspeed. The target is at 1,000 ft. with a 0 to 400 knot selectable closing rate. The initial range to the target is 6 nautical miles for both stern attacks. The instructor selects the target azimuth (40 degrees left to 40 degrees right in 10 degree steps) and the target size (light aircraft, fighter, light bomber or heavy bomber). In the trainer, the student pilot has no control over the simulated interceptor flight path, therefore the interceptor appears to fly a perfect lead collision course in heading and altitude regardless of student action. This simplification greatly reduces the cost of the trainer and is entirely consistent with the training objectives established for the part-task trainer. A lead collision ocurse is roughly the trajectory flown by an F-106A interceptor during an actual radar intercept. In an operational situation, the ground-controlled intercept (GCI) controller vectors the interceptor onto a lead collision course. In the aircraft, if the pilot follows the steering information displayed by the MA-1 after lock-on, he will fly a lead collision course. In the trainer, the steering information indicates that the interceptor is on a lead collision course. Therefore, a pilot controlled flight path will not vary much from this profile. The existing flight simulator is used to teach those flying skills that are used in conjunction with the MA-1 to successfully complete an intercept. In the trainer, the target remains at the selected azimuth as the interceptor closes on the target at the selected rate and climbs or descends at a constant rate so that the interceptor reaches the target altitude when the range reaches zero. Of course, if the student accomplishes the intercept properly, he will launch weapons and receive a pullout collision warning before this point.

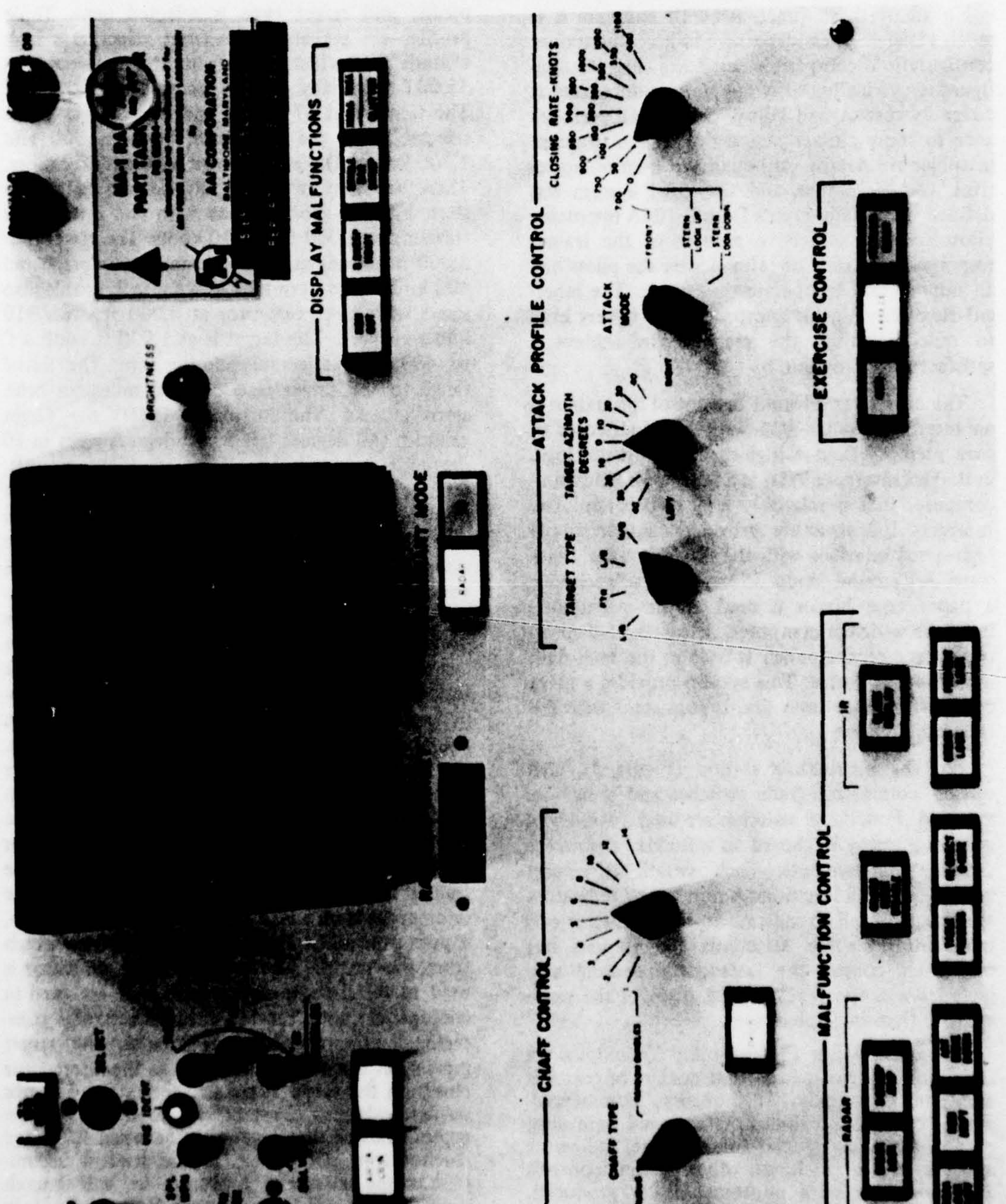


Figure 3. **Instructor console.**

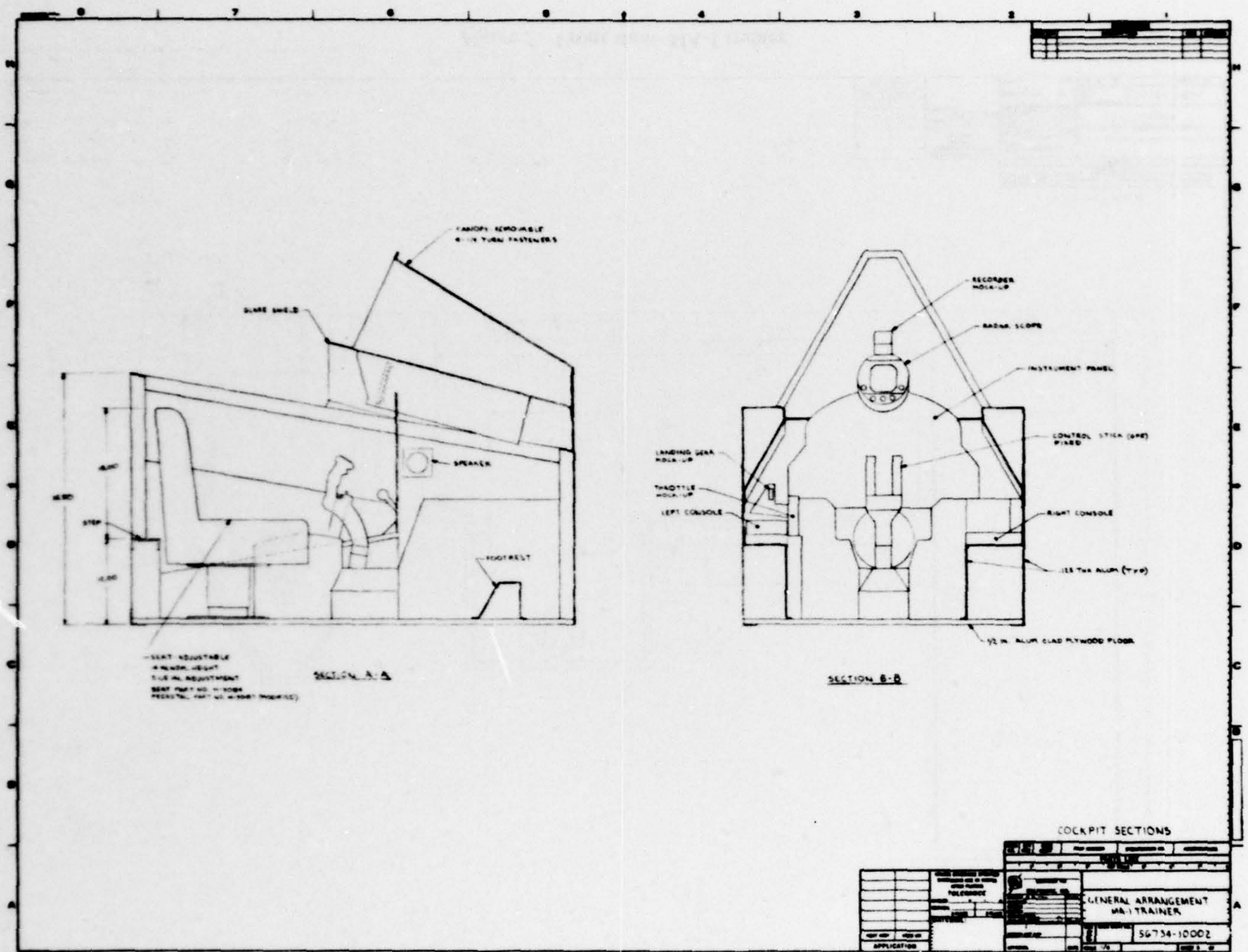


Figure 4. **Cockpit sections—MA-1 trainer.**

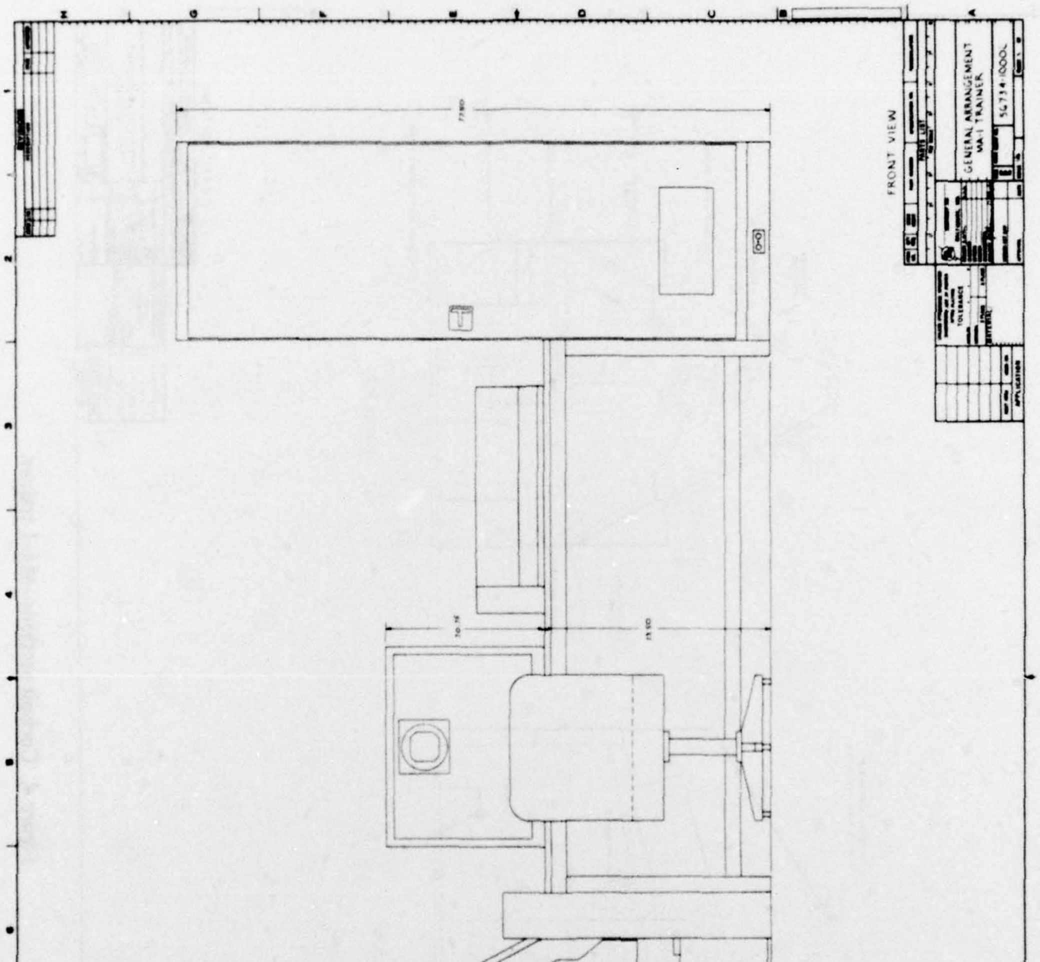


Figure 5. **Front view–MA-1 trainer.**

Table 3. **Instructor Console Controls and Indicators**

Nomenclature	Description	Function
Power		
Emergency Stop	Momentary pushbutton switch-indicator (red)	Removes all power from MA-1 Trainer.
On-Off	Key switch.	Applies and removes power to the MA-1 Trainer.
MA-1 Scope Repeater	Cathode ray tube with illuminated instrumented bezel.	Provides instructor with exact duplication of all displays and data viewed on Student Cockpit scope.
Brightness	Potentiometer	Permits instructor to vary brightness level of displays on his MA-1 SCOPE REPEATER.
Armament Control		
SPL WPN Armed	Indicator light	Indicates that the special weapon is armed.
ARM	Indicator light	Indicates that the selected armament is armed.
SELECT	Annunciator	Indicates the availability of the selected armament.
SPL WPN REL Lock	Annunciator	When special weapon is selected, indicates the LOCK/UNLOCK condition of special weapon.
SPL WPN, VIS IDENT, RAD, ALL, IR Missiles (SALVO not used)	Indicator lights (5)	Indicates the position of the Armament Selector switch in Student Cockpit.
AIR 2A CB IN	Electrically bailed switch-indicator	When illuminated, indicates that AIR 2A CB ARM SAFE MONITOR PWR circuit breaker in Student Cockpit is closed. When pressed, causes circuit breaker to trip (open).
LOAD	Alternate action switch-indicator	Provides the MA-1 system with armament loaded condition.
Range to Target	Digital display	Indicates the range of simulated target.
Dominant Mode		
Radar, IR	Indicator lights (2)	When illuminated, indicates operating mode of MA-1 system.

Table 3 (*Continued*)

Nomenclature	Description	Function
Display Malfunctions		
RGM OUT	Alternate action switch-indicator	Causes range gate marker on scopes to disappear.
B-SWEEP NOISY	Alternate action switch-indicator	In manual track mode, causes B-sweep to darken and appear noisy.
Single Bar Sweep	Alternate action switch-indicator	Causes MA-1 system to search in 1 bar scan pattern.
Xmas Tree	Electrically bailed switch-indicator	Causes Christmas tree to be displayed when ATTACK MODE switch is set to FRONT ATTACK and either 16 or 40 miles range is selected.
Clutter		Causes clutter level to increase when ATTACK MODE switch is set to either STERN LOOK-UP or LOOK-DOWN.
Chaff Control		
Chaff Type Continuous Random Bundles	Two-position switch	Provides for selection of either continuous or random bundle chaff.
1,2,3,4,5,6,8,10, 12,14	Ten-position rotary switch	When RANDOM BUNDLES is selected, permits selection of the number of bundles of chaff.
DROP	Electrically bailed switch-indicator	Causes chaff to be dropped. If CONTINUOUS is selected, chaff will be dropped until DROP switch is manually deactivated: If RANDOM BUNDLES is selected, the selected number of chaff bundles will be dropped and the DROP switch will deactivate. A chaff drop can only be initiated when the MA-1 Trainer is in the RUN mode.
Attack Profile Control		
Target Type L/A-FTR-L/B-H/B	Four-position rotary switch	Provides selection of target aircraft.
Target Azimuth Degrees Left 40,30,20,10,0 Right 10,20,30,40	Nine-position rotary switch	Provides selection of target bearing in degrees.

Table 3 (*Continued*)

Nomenclature	Description	Function
Attack Mode Front STERN Look-up STERN Look-down	Three-position rotary switch	Provides selection of attack profile. In FRONT position, the interceptor is in a frontal attack at 32,000 ft. and the target is at 37,000 ft. In the STERN LOOK-UP position, the interceptor is in a rear attack at 2,000 ft. and the target is at 3,000 ft. In the STERN LOOK-DOWN position, the interceptor is in a rear attack at 2,000 ft. and the target is at 1,000 ft.
Closing Rate – Knots 700,750,800, 850,900,950, 1000,1050,1100 0,50,100,150, 200,250,300,350, 400	Nine-position rotary switch	Provides selection of target range rate in knots. In FRONT attack mode, a range rate of 700, 750, 800, 850, 900, 950, 1000, 1050, 1100 knots can be selected. In STERN LOOK-UP or STERN LOOK DOWN attack mode, a range rate of 0, 50, 100, 150, 200, 250, 300, 350, 400 knots can be selected.
Malfunction Control		
Radar		
Break Lock	Momentary switch-indicator	Causes radar to lose lock-on.
B-Sweep Jump	Alternate action switch-indicator	Causes B-sweep to jump off of target when lock-on is attempted.
Break Lock Chaff	Alternate action switch-indicator	Causes radar transfer lock-on to chaff if Student Cockpit CHAFF switch is in OFF.
RGM Drift	Alternate action switch-indicator	Causes range gate marker to drift off of the target when lock-on is attempted.
ANT Drive Down	Alternate action switch-indicator	Causes antenna to drive down and off of the target when lock-on is attempted.
Cross Mode Disable	Alternate action switch-indicator	Prevents MA-1 system from cross-moding between Radar and IR mode or between IR and Radar mode.

Table 3 (*Continued*)

Nomenclature	Description	Function
Table Precess	Electrically bailed switch-indicator	Causes the stable table to roll. After student re-erects the stable table, the TABLE PRECESS switch-indicator will be extinguished.
Re-Erect O-Ride	Alternate action switch-indicator	Prevents student from re-erecting the stable table.
IR		
Blank Display	Alternate action switch-indicator	Blanks scope display on both Radar and IR modes.
Break Lock	Momentary switch-indicator.	Causes IR to lose lock-on.
Prevent Lock	Alternate action switch-indicator	Prevents student from locking on to the IR target.
Exercise Control		
Run	Electrically bailed switch-indicator	Causes the dynamic parameters of the exercise (range rate, chaff drops, armament firing, etc.) to proceed.
Freeze	Electrically bailed switch-indicator	Causes the dynamic parameters of the exercise to halt. The ARMAMENT CONTROL, DISPLAY MALFUNCTIONS, and MALFUNCTION CONTROL switches remain active.
Prob Reset	Electrically bailed switch-indicator	Terminates exercise and permits Keyboard/Printer to print results of previous exercise. Permits setting up of a new exercise.

When the instructor has completed the profile selection, he selects any malfunctions he wishes to insert into the student's MA-1 system. The instructor may select a greatly increased ground clutter level which will force the student to use IR to acquire the target, or he may select the "Christmas Tree" anomaly to attempt to confuse the student during the high altitude profile. He may also configure the interceptor with a full load of weapons or with an unloaded aircraft if he wishes to train the student in the dry pass procedures used frequently in the aircraft during training flights. He then initiates the problem by pressing RUN. The interceptor starts closing on the target at the selected rate. The instructor has a range readout that informs him continuously of the target range. He normally informs the student of the target range and azimuth periodically to simulate the GCI controller function. He can easily observe all student actions and observe the scope repeater to determine if the student is using his scope properly. During the problem he can insert or remove malfunctions and/or simulate a target dropping chaff. He can drop the chaff bundles continuously or randomly. The instructor can also freeze the problem and correct the student if necessary.

Table 4 lists the student cockpit controls and displays that are functional. Basically, the student

Table 4. **Functional Cockpit Controls, Switches, Indicators and Displays**

Nomenclature	Description	Function
MA-1 Power Panel		
Horizon Adjust/ Stable Table Re-Erect	Potentiometer with momentary pushbutton.	Adjusts artificial horizon position and initiates stable table re-erect cycle.
Power	Six-position rotary switch.	Applies and removes MA-1 power.
Stable Table	Annunciator	Indicates re-erect cycle in progress.
Radar/IR Selector Panel		
Range Scale	Four-position rotary switch.	Selects range scale: 4 mile, 16 mile, 40 mile short pulse, 40 mile long pulse.
Tune	Four-position rotary switch.	Selects tuning mode: Normal, Fast Min, Fast Max, Sniff.
IR Mode	Three-position toggle switch.	Selects IR seeker mode: stowed, slaved to radar antenna, radar scans independently.
Chaff	Three-position toggle switch.	Selects anti-chaff tracking: Off, Gate, All.
Nose/Tail	Two-position toggle switch.	Selects leading edge or trailing edge tracking during initial tracking.
IF Gain Mode	Two-position toggle switch.	Selects manual IF gain or AGC.
Radar/IR Control Panel		
Azimuth Scan	Four-position rotary switch.	Selects azimuth search limits: Broad, Left sector, Right sector, Center sector.
EL Scan	Three-position toggle switch.	Selects search raster bars: 1-bar, 2-bar, 4-bar.
IR Threshold Video	Potentiometer	Controls IR video threshold for displayed IR video.
IR Tone	Potentiometer	Controls IR audio to null out background IR noise.
IR Volume	Potentiometer	Controls volume of IR audio.

Table 4 (*Continued*)

Nomenclature	Description	Function
Armament Control Panel		
Armament Selector	Five-position rotary switch.	Selects armament type: Special weapons, Visual Identification, Radar missiles, All missiles, IR missiles.
ARM/Safe	Two-position toggle switch.	Simulates the arming signals for weapons.
Lock/Unlock	Two-position toggle switch.	Simulates the insertion or removal of the safety pin in Special Weapon launch rack.
Select	Annunciator	Indicates if selected armament is available.
Special Weapon Lock	Annunciator	Simulates the position of Special Weapon safety pin.
Special Weapon Armed	Push-to-Test Indicator Light	Indicates when Special Weapon is armed.
AIR-2A Circuit Breaker Panel		
ARM/Safe/Monitor PWR	Circuit Breaker	Applies armament power to Special Weapon armament circuits.
Radar Scope Hood		
Erase Intensity	Potentiometer	Controls scope storage time.
Attack Intensity	Potentiometer	Controls brightness of attack display characters.
Dimmer	Potentiometer	Controls brightness of entire scope.
IF Gain	Potentiometer	Controls radar sensitivity.
Video Gain	Potentiometer	Controls scope contrast.
MA-1 Radar Scope	CRT	Displays radar returns, IR received signals and symbology.
Mode 2	Indicator Lamp	Indicates IR head unstored.
Mode 3	Indicator Lamp	Indicates when Tail is selected on Nose/Tail.
Mode 4	Indicator Lamp	Indicates when Chaff switch is not in OFF position.
Mode 5	Indicator Lamp	Indicates when weapon is armed.
Mode 6	Indicator Lamp	Indicates when trigger is depressed.

Table 4 (*Continued*)

Nomenclature	Description	Function
VIWARN	Indicator Lamp	Indicates lock-on has occurred with no weapon selected.
Range Scale	Three indicator lamps.	Indicates if 4,16 or 40 mile range is selected.
Range Rate Scale	Ten Indicator Lamps	Indicates that lock-on has occurred and provides a scale to read range rate gap.
Control Stick		
Antenna Control	Two-Degree Motion Control Stick	Positions radar antenna or seeker head in azimuth and positions radar range gate.
Elevation	Thumbwheel potentiometer	Positions antenna and seeker in elevation.
Return to Search	Momentary pushbutton switch	Initiates search mode.
Radar/IR	Alternate action pushbutton switch.	Selects radar or IR dominant modes.
Expanded C Scan/Lead Collision/Pursuit	Three-position momentary slide switch	Controls display of IR expanded C-scan and selects lead collision or pursuit attack mode.
Action Switch	Three-position momentary trigger switch	Selects antenna control modes and initiates lock-on.
Armament Trigger	Three-position momentary trigger switch	Enables armament launch.

can use all MA-1 features except the electronic counter-countermeasures (ECCM) controls. He attempts to detect, acquire, track the target, and launch weapons before he closes to minimum firing range. All weapons arming and safety functions are simulated and a launch is aborted if the aiming and launching rules are violated. The system can be locked onto the altitude line, ground returns or chaff if the student pilot attempts to acquire them. If he fails to recognize this, he can track and launch against one of these false targets.

At the completion of the problem, the instructor pushes PROBLEM RESET. A hard copy record of the problem then is printed on the keyboard/printer. The record includes the student's name, date and sortie number, the initial problem conditions, and actions by the instructor or student during the problem. Each action is labeled with its time in the problem. For example, all lock-ons are recorded along with a record of what actually was locked onto each time. The instructor then can initiate a new problem. The instructor does not need to know how to operate the Interdata computer. In fact, the control panel is inside the simulation cabinet and is used only by maintenance personnel Due to the Interdata power fail safe features, the entire trainer can be turned on and off from the instructor's console and operation is resumed automatically.

VII. EVALUATION

An investigation concerning the impact and utilization of this device is currently being conducted. The product of this effort will be a

technical report documenting the acceptance/utility of the device, in addition to an evaluation of the behavioral design techniques employed.

The objectives of this plan are as follows:

1. Determine training effectiveness of the device by evaluating student performance on the MA-1 system before and after introduction of the device into the training curriculum.

2. Evaluate the utility and effectiveness of various features incorporated in the device.

3. Assess instructor and student acceptance of and attitudes toward the device.

4. Make interim and final recommendations to the users concerning optimal interface of the device into the F-106A training program.

In order to accomplish these objectives, the five following types of data will be collected:

1. Instructor ratings of in-flight student performance. These data are available historically from June 1975 and will serve as control data for the evaluation. These data contain information, by sortie, regarding acquisition and lock-on ranges for radar and IR targets as well as operation during degraded modes.

2. Student notebooks and performance records which provide periodic evaluation of student MA-1 related performance along a 4-point scale. These ratings (by instructors) may reflect shifts in student performance between pre- and post-trainer sample groups. In addition, since ratings are provided for specific facets of MA-1 performance, they are expected to spotlight the nature of any performance change found.

3. Following graduation, student ratings will be accomplished during on-the-job training at operational squadrons. The squadron supervisors rate the new assignees on the same scale used in the training squadron. These data normally are collected in addition to estimations of the number of flights necessary to demonstrate proficiency on specified tasks. These data will be used to identify changes in student performance that are attributable to the use of the new training device.

4. At the training squadron, attitudinal surveys and interviews will be administered. These will examine the student, instructor and supervisor acceptance of the device, to include strengths, weaknesses and maintainability.

5. As part of the trainer design, a hard copy printout of student actions and trainer conditions is printed for every sortie. These data will provide a measure of the utilization/frequency in the selection of various instructional features. Each of these data sources, independently and in combination, can provide an assessment of the overall training impact of the device. In addition to indicating the types of training tasks most effectively handled by the behavioral data design techniques employed.

VIII. CONCLUSIONS

The objectives of this effort have been accomplished. Use of the behavioral design technique has resulted in a low-cost part-task trainer that shows preliminary evidence of providing effective hands-on training for F-106A student pilots.

Obviously, the ultimate success of this effort will be demonstrated by the improvement in the quality of pilots produced by the new training program using this trainer in conjunction with existing training equipment.

However, several conclusions can be drawn at this time. First, it is entirely feasible to define a simulation device in terms of the tasks it must be capable of training. Second, utilization of high-quality commercial components and best commercial manufacturing practices can result in a relatively simple and reliable device suitable for a classroom environment. Third, placing the primary burden of simulation in the software along with a television raster-type scope simulation results in considerable flexibility and good simulation of even the most complex airborne attack radar scope displays. Fourth, significant participation by personnel representing the ultimate Air Force user, in all stages of development, considerably improves the quality and acceptance of the delivered training device. It ensures that important cues are well simulated and resources are not wasted in simulating irrelevant cues and that user acceptance is high. In addition, these methods, when used together, result in a low-cost, reliable device that is capable of training F-106A student pilots in the identified tasks. Whether the trainer is cost effective remains to be seen; however, these facts greatly enhance the probability of achieving this goal.

Finally, consideration must be given to applying this approach and solution to other aircraft training problems. The part-task trainer concept, task-oriented specification and all of the other techniques used for this effort can be applied to a wide variety of training problems.

REFERENCES

AF Manual 50-2. *Training: Instructional system development.* Washington, D.C.: Department of the Air Force, 31 July 1975.

AF Pamphlet 50-58. *Training: Handbook for designers of instructional systems* (Vols I–V). Washington, D.C.: Department of the Air Force, 30 January 1974.

Cream, B.W., Eggemeier, F.T., & Klein, G.A. Behavioral data in the design of aircrew training devices. In R. N. Hale, R. A. McKnight, & J. R. Moss (Eds.), *Proceedings of the 19th Annual Convention of the Human Factors Society,* 1975, pp. 260–265.

Cream, B.W., & Lambertson, D.C. *Functional integrated systems trainer: Technical design and operation.* AFHRL-TR-75-6(II), AD-A015 835. Advanced Systems Division, Air Force Human Resources Laboratory, June 1975.

Cream, B.W., & Woodruff, K.R. *Functional integrated systems trainer: Description and evaluation.* AFHRL-TR-75-6(I). Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, in press.

Goldstein, I.L. *Training: Program development and evaluation.* Monterey, CA: Brooks/Cole Publishing Co., 1974.

Klein, G.A. Problems and opportunities in deriving training requirements for the design and utilization of simulators. *Proceedings of the First International Learning Technology Congress and Exposition,* Volume IV, July 1976. (a)

Klein, G.A. *Phenomenological analysis of proficient man/machine performance.* Paper presented at the 38th Military Operations Research Society Meetings, December 1976. (To be published as an AFHRL Technical Report, "A Phenomenological Approach to Improving Complex Man/Machine Performance"). (b)

Miller, R.B. *Handbook on training and training equipment design.* WADC-TR-53-136. AD-16 859. Wright-Patterson AFB, OH: Wright Air Development Center, June 1953.

Miller, R.B. *A method for determining task strategies.* AFHRL-TR-74-26, AD-783 847. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, May 1974.

Montemerlo, M.D., & Tennyson, M.E. *Instructional systems development: Conceptual analysis and comprehensive bibliography.* Technical Report NAVTRAEQUIPCEN IH-257. Orlando, FL: Naval Training Equipment Center, February 1976.

Smode, A.F. Recent developments in instructor station design and utilization for flight simulators. *Human Factors,* 1974, 16, 1–18.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977—771-122/79